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Dobbs Ferry, N. Y.

PROJECT MICHAEL

Contract N6-ONR-27135

Technical Report No. 23

Transmission of Sound from Deep to Shallow Water

by

A. N. Guthrie

W. A. Nierenberg
Director

Research Sponsored by
Office of Naval Research

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This report consists of 20 pages

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TRANSMISSION OF SOUND FROM DEEP TO SHALLOW WATER

by

A. N. Guthrie

Hudson Laboratories' Operation 12 was conducted in early December of 1952 to study the transmission of sound from deep water over the Continental Rise to listening stations located in various depths of water over the Continental Slope. Pressure levels from shallow explosive sources were measured at four listening stations located at water depths of 180, 280, 480, and 600 fathoms, respectively.

Two ships, the USS ALLEGHENY (ATA 179) as shooting ship and the USFWLS ALBATROSS III as listening ship, were used to carry out the field operations in an area south of Montauk Point, Long Island.

I. THE EXPERIMENT

The field operations consisted of three range runs made on three successive days with the ALLEGHENY commencing each run at point BAKER (39° 37.5' N, 70° 49.5' W) in 1200 fathoms of water and proceeding at 10 knots on a course bearing approximately 175° T.

Four 1/2 lb TNT-tetryl demolition blocks bound together with marline and friction tape were used as bombs. These bombs were exploded at depths of approximately 40 feet by means of 9 in. non-electric fuses.

The shot signals were received on the ALBATROSS by a Brush AX-58C hydrophone suspended at a depth of 250 to 300 feet below the surface. Plastic floats were attached at regular intervals along the hydrophone cable to reduce the submerged weight of the system to a small value. In order to further eliminate motion of the hydrophone through the water due to ship roll, an elastic suspension system for the hydrophone was used. This system consisted of a 25-foot length of shock cord anchoring the hydrophone cable to the rail and a 50-foot length of rubber, made of bicycle inner tube cut and fastened together end to end, connected across a 100-foot slack section in the middle of the hydrophone cable.

The recording system used on the ALBATROSS is shown in the block diagram of Fig. 1. The geophysical voltage amplifier has an essentially flat response from 10 cps to 1500 cps. The SKL electronic filter was set at 20 cps high-pass. The Magnecorder tape recorder was operated at 7 1/2 in/sec tape speed. The response of the hydrophone on the ALBATROSS was recorded on channel 2 and a radioed shot signal from the ALLEGHENY was recorded on channel 1 of the recorder. A break-circuit chronometer record was recorded on channel 1 along with the radioed shot signal. In this way, a means of measuring the travel times of the shots was provided.

The three range runs, in the order in which they were made, are designated Event CHARLIE, Event DOG and Event BAKER. Figure 2 shows the tracks of the ALLEGHENY and the listening stations occupied by the ALBATROSS for each of the three range runs.

Event CHARLIE was carried out between 0800 and 1700 hours on December 7, 1952. The ALBATROSS was anchored up the Continental Slope in 280 fathoms of water at 39° 55' N, 70° 52.5' W. The sea state was 2 to 3 throughout the run. A bomb drop was made every 12 minutes (4 kiloyards) to a point about 190 kiloyards south of point BAKER.

Event DOG took place on 8 December 1952 between the hours 0800 and 1900. At the beginning of the run, the ALBATROSS was hove to at approximately 39° 50.5' N, 70° 51.5' W in 480 fathoms depth. After four hours, the ALBATROSS was moved 3 kiloyards south to a depth of 600 fathoms. During the remainder of the run, depth varied from a maximum of 620 fathoms, measured at 1500 and 1622 hours, to a minimum of 560 fathoms, measured at 1900 hours at the end of the run.

During the run, the sea state changed from 0 at the beginning to a state of about 1 by late afternoon. The wind direction shifted from SSE to E and the force increased from 0 to 1 during the course of the run.

A bomb drop was made every 12 minutes (4 kiloyards) out to a distance of about 225 kiloyards from point BAKER.

Event BAKER was carried out on 9 December 1952 between 0800 and 1700 hours with the ALBATROSS anchored in 180 fathoms of water at 39° 58.5' N, 70° 53' W. Sea state was 2 at the beginning and changed to 3 before the end of the event.

A bomb drop was made every 12 minutes until a distance of about 175 kiloyards from point BAKER was reached.

II. ANALYSIS OF RECORDINGS

The analysis of the shot signals recorded on magnetic tape was made by using an energy integrating system[1] composed of analog computer elements manufactured by George A. Philbrick Researches, Inc., of Cambridge, Massachusetts. These elements are the coefficient, squarer, adder and integrator in the block diagram of Fig. 3.

The shot signals reproduced by playback of the magnetic tapes were filtered to the desired pass-band and then amplified by the Radio Craftsmen 500 amplifier and the coefficient to give a peak signal input to the squarer of 25 to 30 volts. A recording of the signal input to the squarer was made on channel 1 of the Brush recorder which was calibrated so that the peak voltage of this signal could be read.

The output of the squarer, which was proportional to the square of its input, was passed through the adder. The adder, a component which can be set to add to or subtract from the signal a small steady voltage, was used in this system to remove from the input to the integrator any steady noise which was recorded on the tape or originated in the system. Assuming random phase distribution in the noise, the output of the squarer equals $S^2 + N^2$, where S and N are respectively proportional to the shot signal voltage and the noise voltage in the input to the squarer. The adder can be set to subtract a steady voltage equal to N^2 from the output of the squarer and thus render the input to the integrator equal to S^2, provided the noise level remains constant.

A recording of the output voltage of the integrator vs time was made on channel 2 of the Brush recorder. This voltage was proportional to $\int S^2 dt$ which, since S was proportional to the shot signal pressure p at the hydrophone, was also proportional to $\int p^2 dt$ for those cases where the noise level remained constant throughout the period of integration.

The three oscillograms of Fig. 4 were produced with this system. The pass-band used was 30 to 60 cps. When higher frequencies were used, it was necessary to rectify the input to channel 1 of the recorder by use of a diode detector because the Brush recorder will not respond satisfactorily to frequencies above 100 cps.

In two of the three oscillograms, the pen trace on channel 2 is flat both before and after the shot arrival. This is an indication that the adder was properly set to cancel the steady background noise. The trace on the oscillogram for Event CHARLIE is flat before but not after the shot arrival because a burst of low frequency noise closely followed the shot arrival. Similar noise bursts appearing in many of the oscillograms of Event CHARLIE have complicated the analysis of the recordings of this range run. The source of these noise bursts is not definitely known, but it is believed to have been the high-pass filter used in the recording system on the ALBATROSS.

The rise of the pen trace on channel 2 of the oscillogram between times t_1 and t_2 is proportional to $\int_{t_1}^{t_2} p^2 dt$. This integral is proportional to the energy per unit area which reaches the hydrophone during the time interval $t_2 - t_1$.(2) Thus, the total energy in the shot arrival and the energy in the individual bottom reflection orders may be obtained by reading the trace rise during the appropriate time interval and applying the various gain factor of the recording and analyzing systems to the reading.

III. QUALITATIVE RESULTS

The qualitative differences in transmission to the three listening stations are shown by the oscillograms in Fig. 4. The three oscillograms were made at the 180-fathom, the 280-fathom and the 600-fathom listening stations, respectively. On each oscillogram, channel 1 is a recording of the signal from the shot and channel 2 is a recording of $\int p^2 dt$. The pass-band used was 30-60 cps and the ranges of the shots were 108-110 kiloyards from the respective listening stations.

The marked difference in appearance of the oscillogram of the 600-fathom station from that of the other two stations is due to the effect of the bottom on transmission. Transmission of sound from a source near the surface to a range of 100 kiloyards in this part of the ocean requires several bottom reflections. Each reflection on an up-sloping bottom rotates the ray toward the vertical by an amount equal to twice the angle of slope of the bottom.(3) As the sound travels up the slope, the water becomes shallower and the rays steeper so that more reflections occur in covering a given distance. When a ray is incident on the ocean floor at an angle steeper than the critical angle, some of the energy carried in the ray is refracted into the bottom. This has two results; the energy in the water is attenuated and the energy arrival at the hydrophone is smoothed out so that the individual bottom reflection orders are no longer separated and well defined.

The smoothing out effect is caused by reflections from discontinuities occurring in the bottom below the ocean floor. Some of the energy which penetrates the bottom is reflected back from these discontinuities into the water and some of this reflected energy reaches the hydrophone. This results in energy arriving at the hydrophone at a fairly steady rate over the period of the arrival rather than in the bursts of the individual bottom reflection orders.

The several well-separated and compact bursts of energy which arrive at the 600-fathom listening station during a period of about 4 seconds is evidence that a number of bottom reflection orders are able to reach this far up the slope without undergoing reflection at angles steeper than critical.

The appearance of the arrival at the 280-fathom station suggests that, at most one, and possibly none, of the bottom reflection orders are able to travel up the slope to this point before becoming so steep that reflection is no longer total.

At the 180-fathom station the energy arrives at an approximately constant rate for a period of about 3 seconds and then tapers off for about a second longer. This appearance is taken to mean that all bottom reflection orders arriving at this point on the slope have undergone several reflections at angles steeper than critical.

IV. COMPARISON OF LISTENING STATIONS

Corrected pressure levels vs distance from point BAKER are plotted in Fig. 6. The pressure levels have been corrected for cylindrical spreading to a range of one kiloyard by addition of 10 log R to the measured pressure levels, and for water absorption by addition of 0.01 $\overline{f^2}$ R, where R is the range from the listening station in kiloyards and $\overline{f^2}$ is the mean square of the frequency over the band in kcps.(4) This graph includes the results for each of the three shot runs in the 30-60 cps and 1000-2000 cps frequency bands.

The curve at the top of the figure is a plot of the surface water temperature vs distance from point BAKER as obtained by bathythermograph lowerings made during Events CHARLIE and DOG.

Point BAKER was the point of departure of the shooting ship for each of the three shot runs. The ranges from the listening ship to point BAKER were 27.6 kyds for Event DOG, 36.6 kyds for Event CHARLIE, and 44.5 kyds for Event BAKER.

Since the pressure levels have been corrected for spreading and for water absorption, differences in pressure levels between any two listening stations must be attributed to the effects of bottom and surface reflections which occur between the two stations.

On the average, these differences between the 480-fathom and the 280-fathom listening stations amount to no more than 3 db in both the 30-60 cps band and the 1000-2000 cps band. The range difference between these two stations is about 8 kyds. For a range difference of about 9 kyds, the differences in pressure levels between the 280-fathom and the 180-fathom listening stations are about 6 db in the 30-60 cps band and about 9 db in the 1000-2000 cps band.

This indicated increase in the rate of energy loss as the sound travels further up the slope is in agreement with the qualitative conclusions regarding the effect which an upward sloping bottom will have on sound propagation.

The 280-fathom listening station appears to have been at about the limit, or slightly beyond the limit, of distance up the slope for which there can be a ray path from a shallow source well out in deep water which will not undergo at least one bottom reflection at an angle which is steeper than the critical angle. Certainly the appearance of the arrivals at the 180-fathom listening station gives evidence that sound energy reached this station only after undergoing one or more partial reflections from the bottom

V. FREQUENCY DEPENDENCE OF TRANSMISSION

A comparison of the pressure levels in each of the five octave bands between 60 cps and 2000 cps with those for the 30-60 cps band is made in the graphs of Fig. 7 for the shots of Event DOG. The curves of this figure are plots of the pressure level differences between the octave band in question and the 30-60 cps band vs range from the listening station.

The pressure level differences between the 60-120 cps band and the 30-60 cps band remain approximately constant for the shots in the range interval 30 kyds to 115 kyds and then falls by about 2 db between 115 kyds and 145 kyds. For the 125-250 cps band, the levels increase relative to those of the 30-60 cps band by about 5 db as the range increases from 30 to 115 kyds and then drop about 6 db in the next 30 kyds. The three octave bands between 250 and 2000 cps show slowly decreasing pressure levels relative to those for the 30-60 cps band as the range increases from 30 to 115 kyds and rapidly falling levels between 115 and 145 kyds.

This dependence of pressure level-range relationship on frequency is attributable to the effects of transmission by surface sound channel and leakage paths. In the octave bands above a frequency of 125 cps, a significant amount of sound energy will reach the hydrophone by transmission along such paths. Below this frequency, sound energy is rapidly attenuated in the surface sound channel because the wavelengths are large compared to the depth of the channel.

The attenuation of sound energy by reflection from the bottom increases with increasing frequency. Thus, as the frequency rises, the fraction of the energy reaching the hydrophone by direct bottom reflection paths decreases and the fraction by surface sound channel and leakage paths increases.

This effect is shown qualitatively by the oscillograms of Fig. 8, where the signals of the energy arrivals at the hydrophone in the six octave bands between 30 and 2000 cps have been recorded by a Brush recorder. The signals have been rectified for frequencies above 60 cps.

The travel time along a path which involves the surface sound channel is shorter than that along any direct bottom reflection path. For all frequencies above 125 cps, there is a prominent energy arrival which precedes the first energy arrival in the 30-60 cps band by almost one-half second. Certainly this energy has traveled by a path which involves the surface sound channel. In the 1000-2000 cps band, this early arrival constitutes the major part of the total energy.

The levels of the 125-250 cps band rise relative to those for the 30-60 cps band in the range interval 30 to 115 kyds because these frequencies combine relatively good surface sound channel transmission with relatively low attenuation by bottom reflection. Between the ranges 115 and 145 kyds, the shooting ship was entering a body of water associated with the Gulf Stream. The temperature of the water at the surface rose from 59° F to 67° F and the surface sound channel largely disappeared. The 6 db drop in the levels of the 125-250 cps frequency band relative to those of the 30-60 cps band between 115 and 145 kyds represents the disappearance of the surface sound channel contribution to the energy reaching the hydrophone.

The still sharper drop in the relative levels of the higher frequencies shows how dependent transmission of these frequencies is on the surface sound channel.

VI. BOTTOM REFLECTION LOSSES

In the shot arrivals at the 600-fathom station, the various bottom reflection orders are well separated and it is possible to measure the energy of each order. Figure 9 is a plot of the corrected pressure levels vs range for the individual bottom reflection orders for the 30-60 cps frequency range. These pressure levels have been corrected for spherical spreading by addition of 20 log R to the measured levels, where R is the range in kiloyards.

The complicated bottom in this area makes it impossible to identify the bottom reflection orders unless the range run was commenced at a sufficiently short range that the bottom reflection of order one appeared, i.e., sound could reach the hydrophone after undergoing only one reflection from the bottom The range at which this run started was certainly too large for this to be possible. Since numbers could not be assigned to the bottom reflection orders, they have been designated C, D, E, F, G, and H in Fig. 9.

The results as plotted in Fig. 9 are consistent with zero loss for bottom reflections at angles more grazing than the critical angle, but are not consistent with a loss of more than 0.25 db/reflection.

Officer and Hersey[3] have reported values for bottom reflection losses from similar experiments in the same general area. They report losses of 1 db/reflection in the frequency range 50-100 cps, 2 db/reflection for 100-200 cps, 3 db/reflection for 200-400 cps, 4 1/2 db/reflection for 400-800 cps and 6 1/2 db/reflection for 800-1600 cps. The very low value of loss for the 30-60 cps range given by this study is consistent with these Woods Hole Oceanographic Institution values.

Scatter of the data for the 60-120 cps frequency band makes it difficult to determine a reflection loss value for this frequency. The data are consistent with a value as low as 0.6 db/reflection or as high as 1.1 db/reflection.

For frequencies above 125 cps, the complicated nature of the propagation makes it impossible to determine a reflection loss value with any assurance from the data of this study.

VII. SUMMARY AND CONCLUSIONS

A study has been made of the transmission of sound up a sloping ocean bottom from explosive sources near the surface to listening stations in shallow water over the Continental Slope at a point south of Montauk Point, Long Island.

Measurements of pressure level as a function of range were made at three listening stations located at three different depths of water.

Analysis of these measurements has shown that sound transmitted up a sloping bottom is attenuated at a rate which increases as the sound travels further up the slope. This effect is attributed to the progressive steepening of the rays by reflections from the up-sloping bottom and the resulting loss of energy by refraction into the bottom when the sound becomes incident on the bottom at angles steeper than critical.

Data taken at a station in 600 fathoms of water have yielded limiting values of bottom reflection losses on the Continental Rise for angles of reflection more grazing than critical which are in general agreement with values obtained by WHOI(3) in the same area.

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REFERENCES

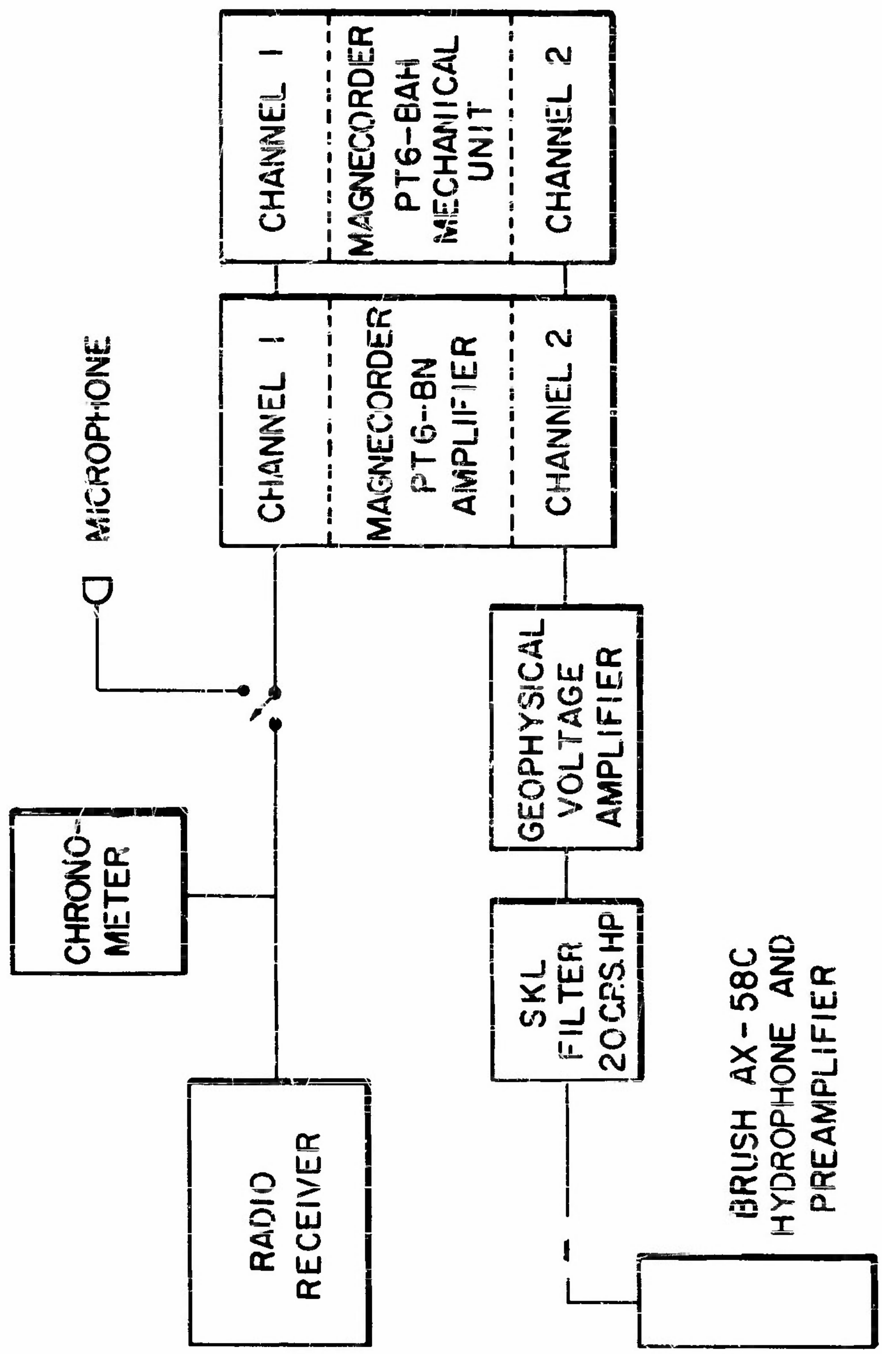
1. Officer, C. B., Jr., and Dietz, F. T. Total energy computations. In Sonar research conducted during the period January 1, 1953 - March 31, 1953. Woods Hole Oceanographic Institution, Reference no. 53-46. June, 1953. pp 5-6. (C)

2. Frosch, R. A. Guthrie, A. N. Loar, H. H., and Poss, H. L. A preliminary report on sound transmission at San Juan, Puerto Rico. Columbia University, Hudson Laboratories, Technical report no. 12. October 1, 1953. (S)

3. Officer, C. B., Jr., and Hersey, J. B. Sound transmission from deep to shallow water. Woods Hole Oceanographic Institution, Reference no. 53-32. August, 1953.

4. Urick, R. J. Recent results on sound propagation to long ranges in the ocean. U. S. Navy Journal of Underwater Acoustics. 1(2S): 57-63. April, 1951. (S)

FIG. 1



RECORDING SYSTEM USED ON USFWLS ALBATROSS 3

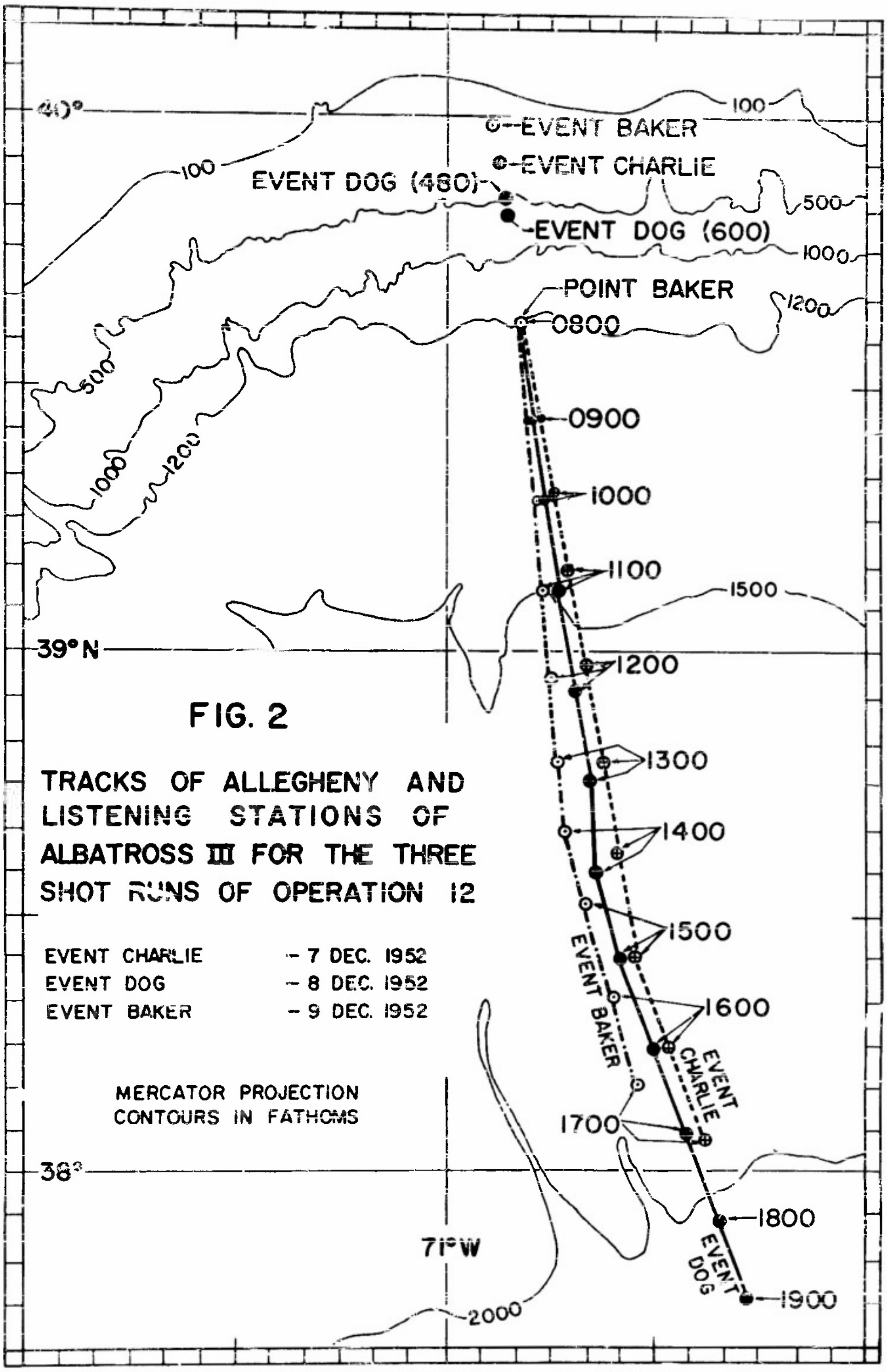


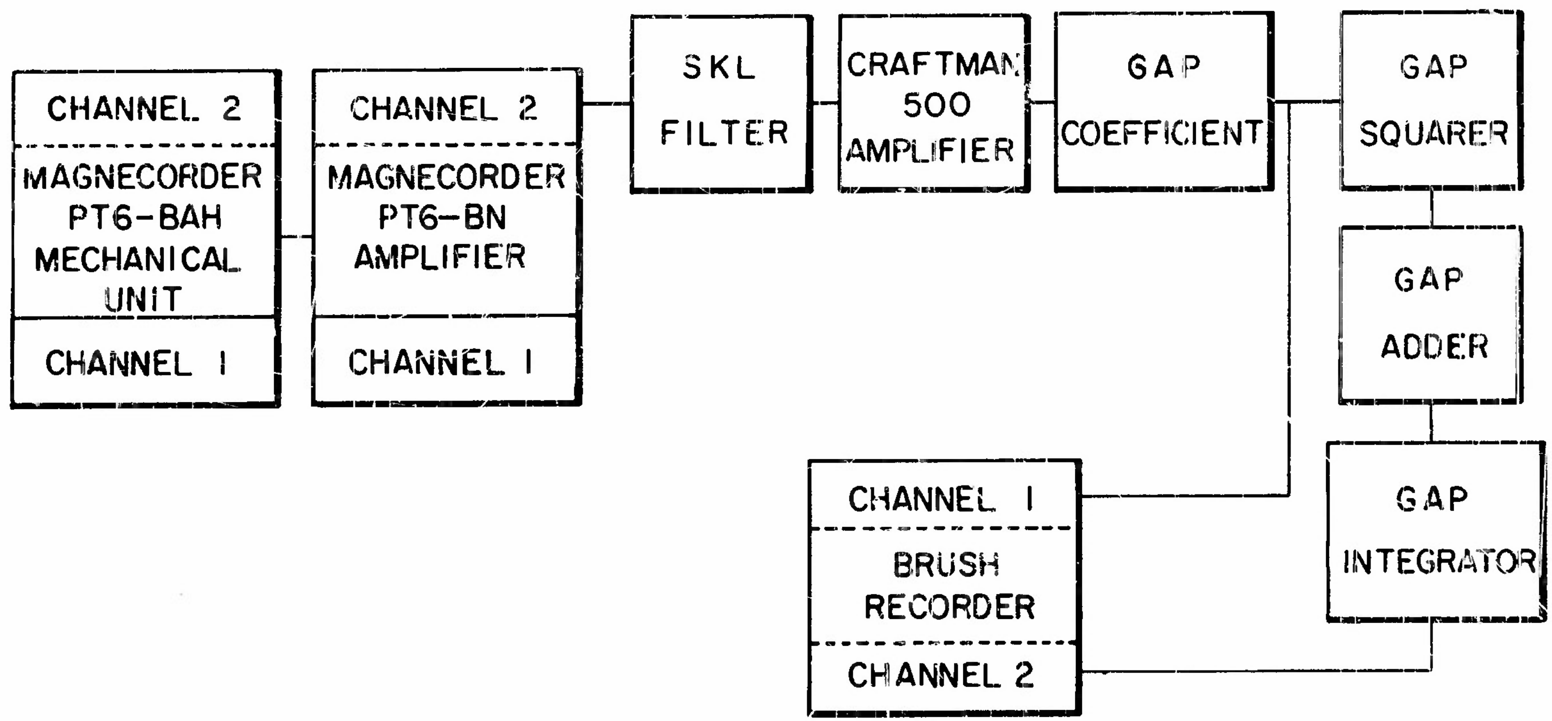
FIG. 2

TRACKS OF ALLEGHENY AND LISTENING STATIONS OF ALBATROSS III FOR THE THREE SHOT RUNS OF OPERATION 12

EVENT CHARLIE - 7 DEC. 1952
EVENT DOG - 8 DEC. 1952
EVENT BAKER - 9 DEC. 1952

MERCATOR PROJECTION
CONTOURS IN FATHOMS

FIG. 3



ENERGY INTEGRATING SYSTEM FOR SHOTS

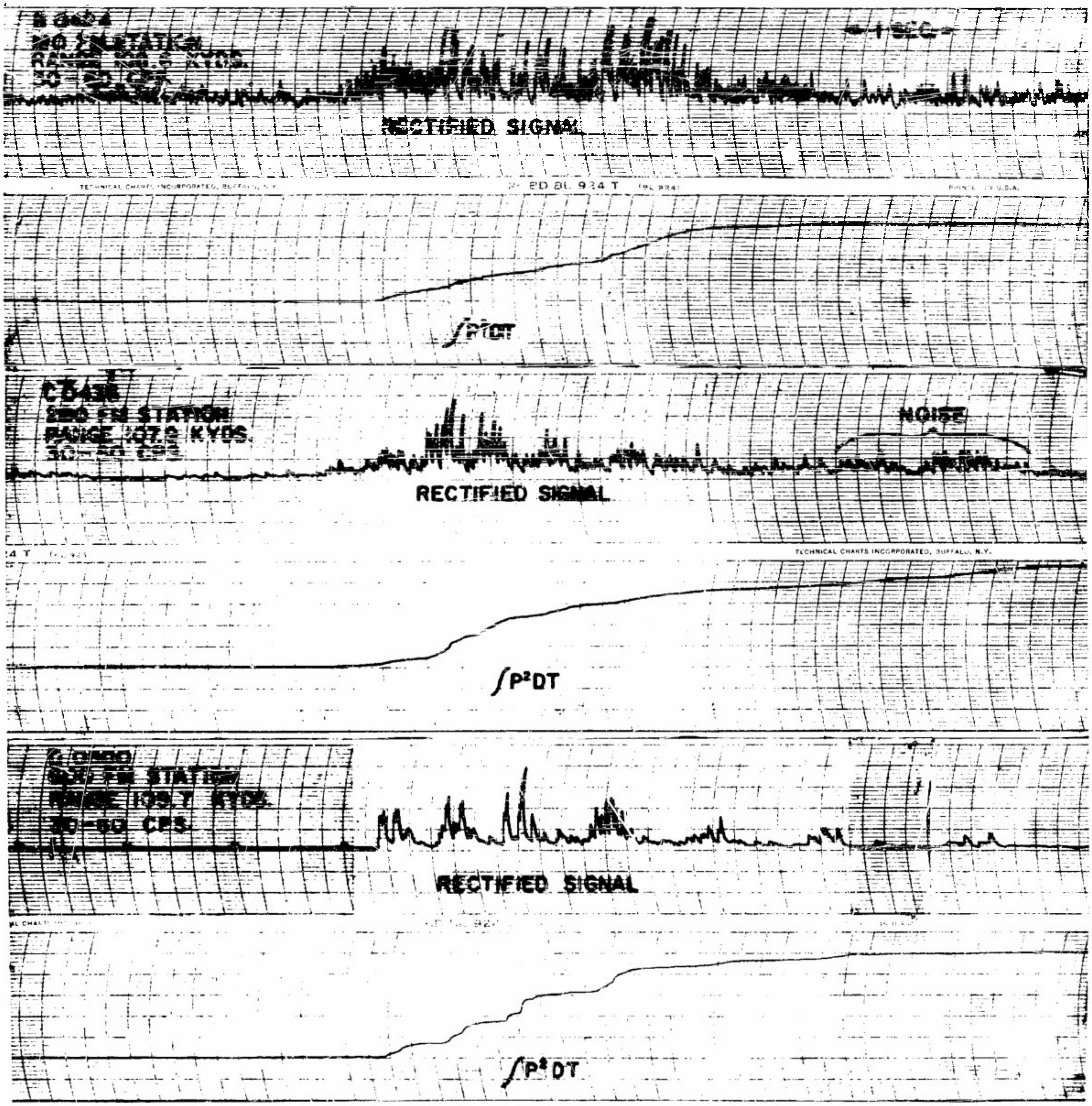


FIG. 4

TYPICAL SHOT SIGNALS AND SHOT ENERGY INTEGRATIONS

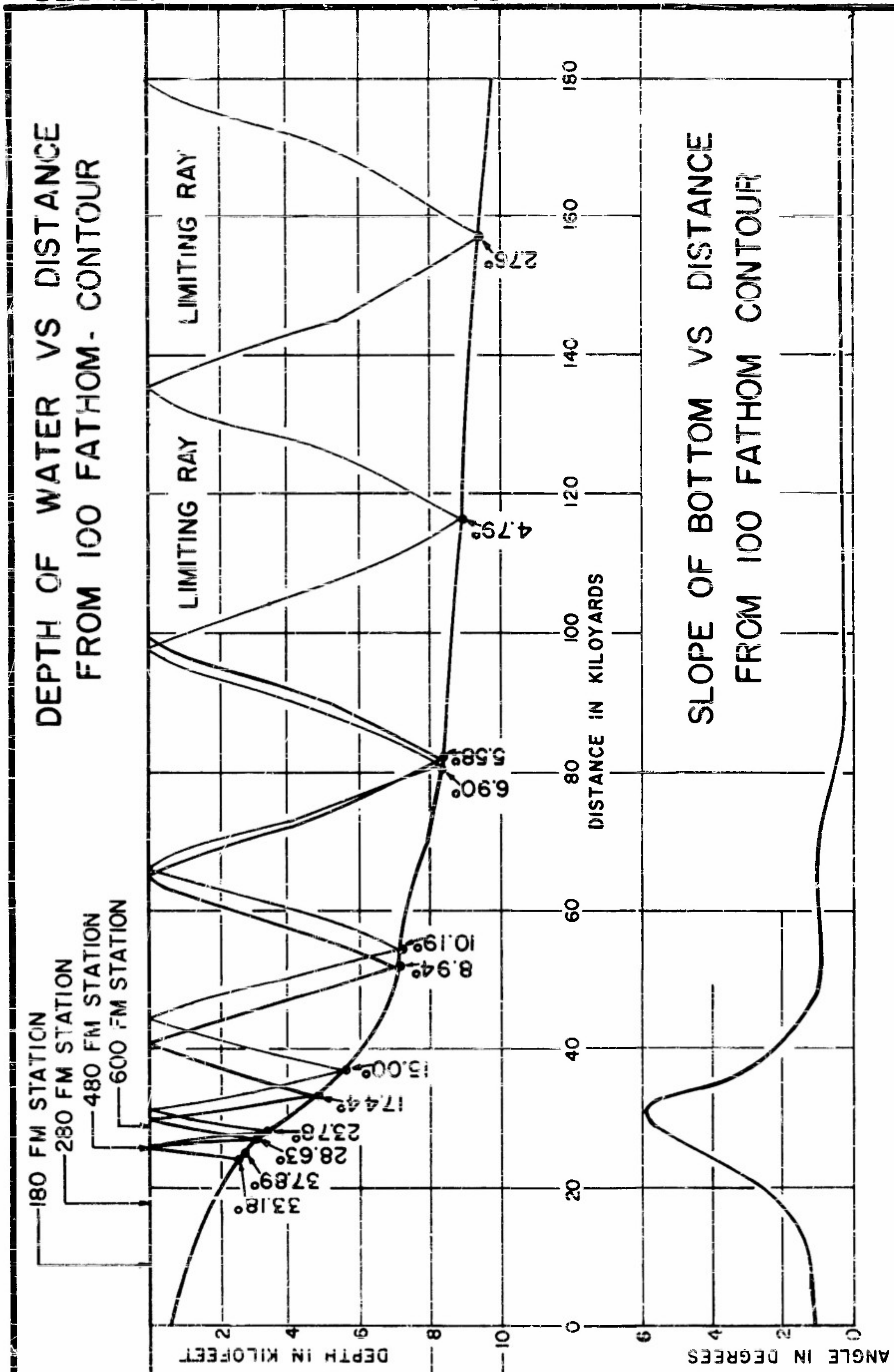

DEPTH OF WATER VS DISTANCE
FROM 100 FATHOM - CONTOUR
180 FM STATION
280 FM STATION
480 FM STATION
600 FM STATION
LIMITING RAY
LIMITING RAY
33.18°
37.89°
28.63°
23.78°
17.44°
15.00°
8.94°
10.19°
6.90°
5.58°
4.79°
2.76°
DEPTH IN KILOFEET
DISTANCE IN KILOYARDS
SLOPE OF BOTTOM VS DISTANCE
FROM 100 FATHOM CONTOUR
ANGLE IN DEGREES

FIGURE 5

SECRET

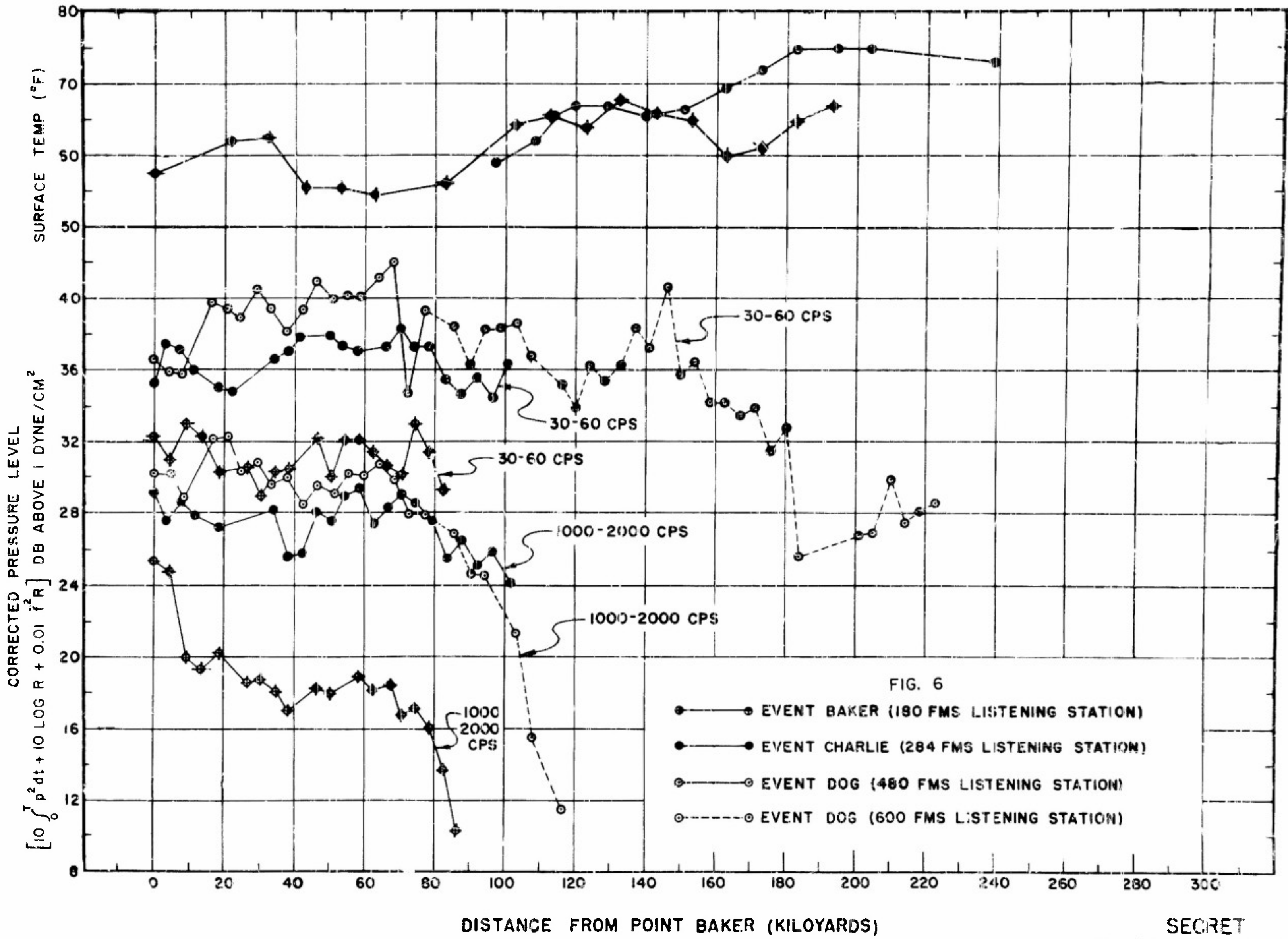


FIG. 6

SECRET
SECURITY INFORMATION

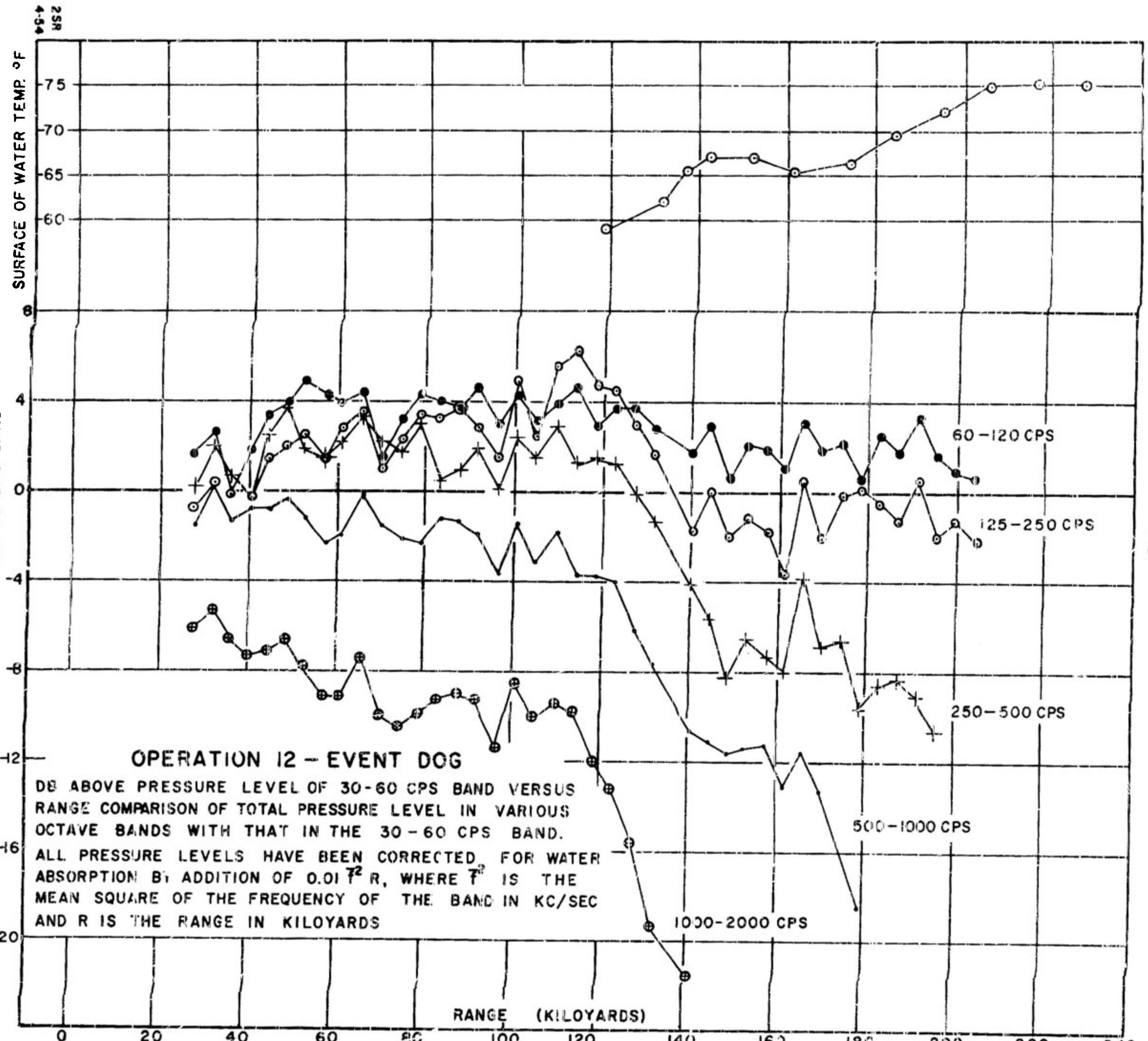

OPERATION 12 — EVENT DOG
DB ABOVE PRESSURE LEVEL OF 30-60 CPS BAND VERSUS RANGE COMPARISON OF TOTAL PRESSURE LEVEL IN VARIOUS OCTAVE BANDS WITH THAT IN THE 30-60 CPS BAND.
ALL PRESSURE LEVELS HAVE BEEN CORRECTED FOR WATER ABSORPTION BY ADDITION OF 0.01 $\bar{f}^2$ R, WHERE $\bar{f}^2$ IS THE MEAN SQUARE OF THE FREQUENCY OF THE BAND IN KC/SEC AND R IS THE RANGE IN KILOYARDS
60-120 CPS
125-250 CPS
250-500 CPS
500-1000 CPS
1000-2000 CPS
SURFACE OF WATER TEMP °F
75
70
65
60
DB ABOVE PRESSURE LEVEL OF 30-60 CPS BAND
8
4
0
-4
-8
-12
-16
-20
RANGE (KILOYARDS)
0
20
40
60
80
100
120
140
160
180
200
220
240
2SR
4-54

FIG. 7

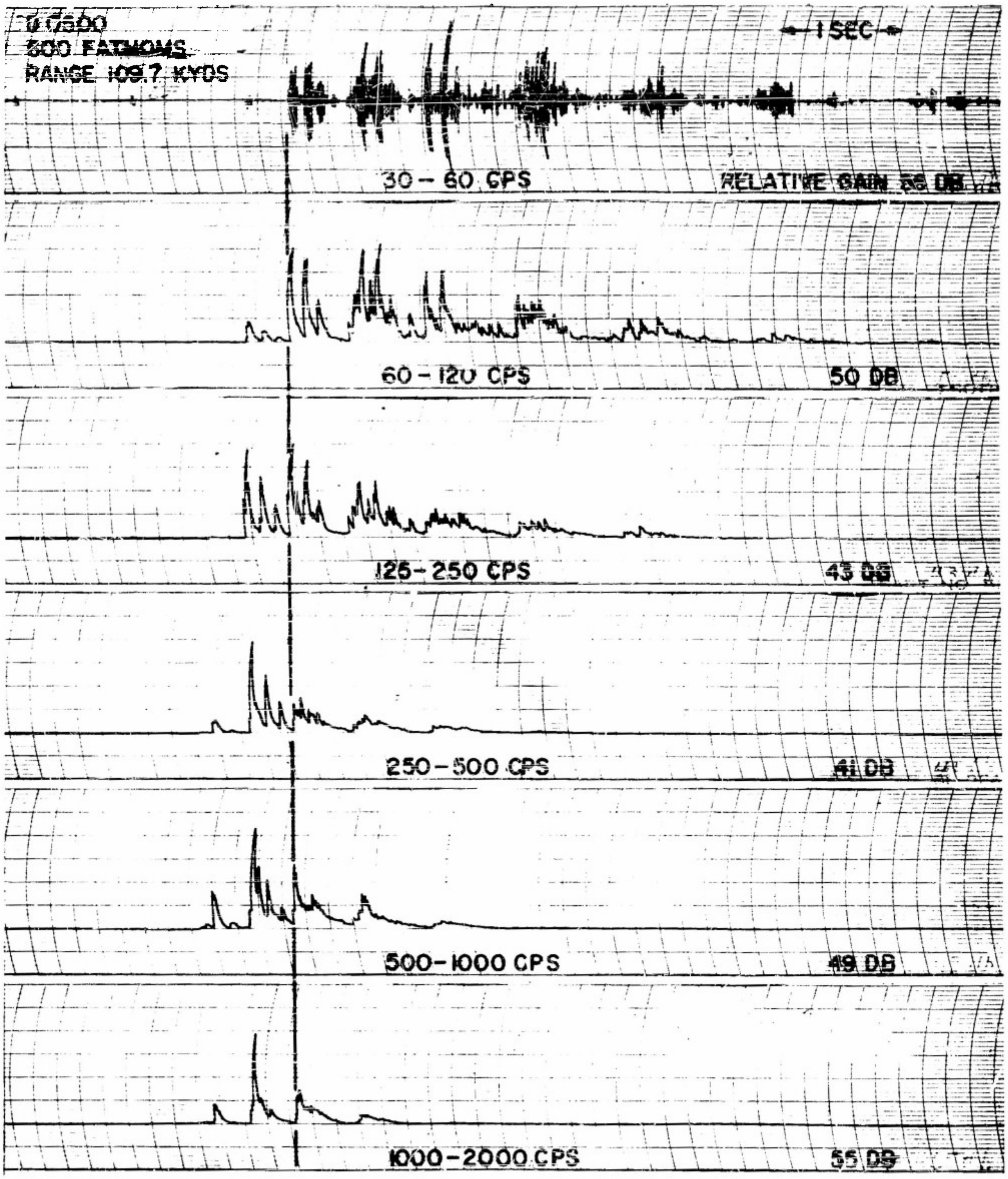
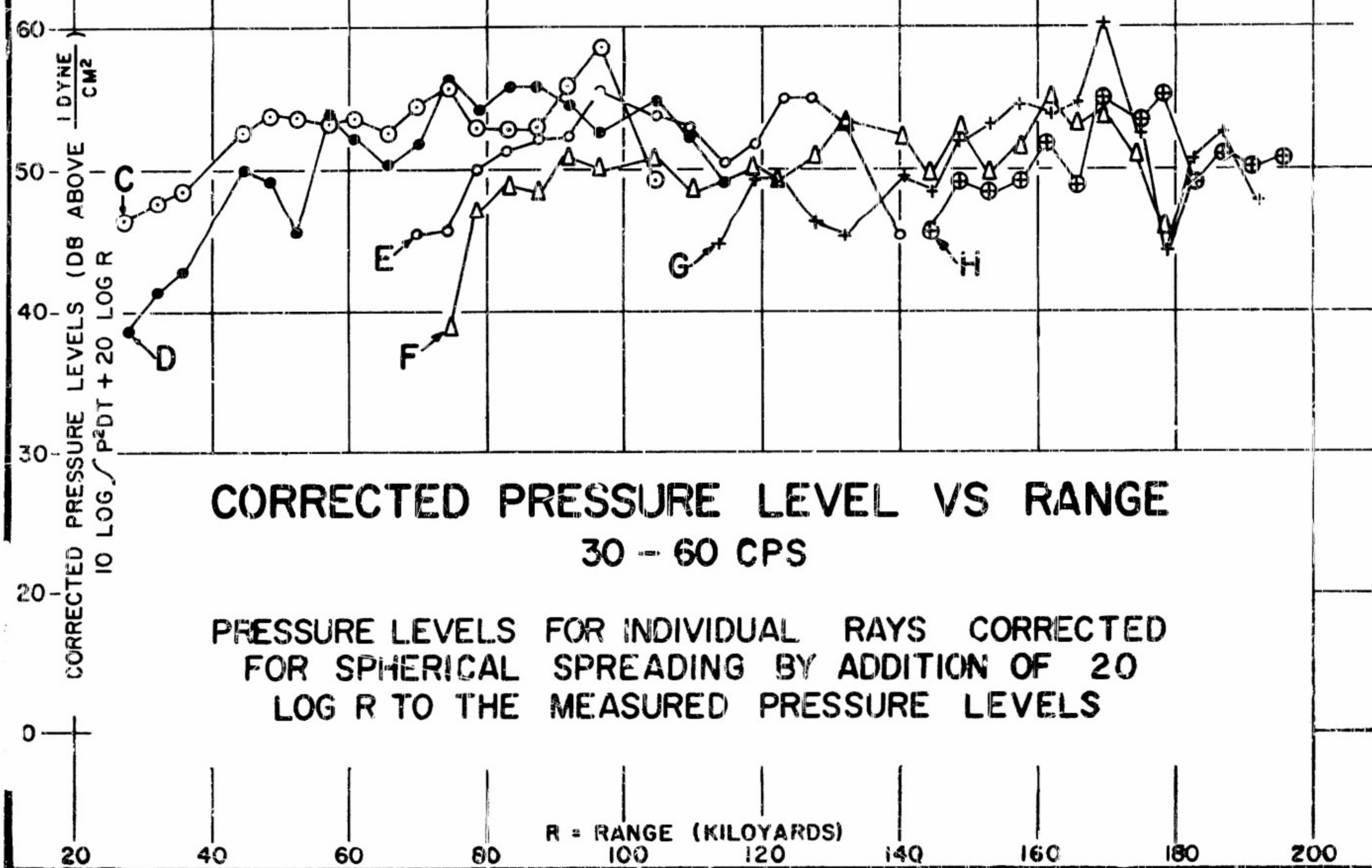


FIG. 8

FREQUENCY DISTRIBUTION OF ENERGY IN SHOT SIGNAL

FIG. 9



CORRECTED PRESSURE LEVEL VS RANGE

30 – 60 CPS

PRESSURE LEVELS FOR INDIVIDUAL RAYS CORRECTED FOR SPHERICAL SPREADING BY ADDITION OF 20 LOG R TO THE MEASURED PRESSURE LEVELS

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